

## Specification

### Title of the Invention

5           Scanning Optical System for Tandem Type Printer

### Background of the Invention

10           The present invention relates to a scanning optical system employed, for example, in a tandem type color laser beam printer.

15           Conventionally, a scanning optical system, which is employed, for example, in a tandem type color laser beam printer is known. Such a color laser beam printer includes a plurality of scanning optical systems and photoconductive drums corresponding to a plurality of color components of a color image formed by the color laser beam printer. In each scanning optical system, a laser diode, a polygonal mirror and an  $f\theta$  lens are provided. The laser beam emitted by the laser diode is deflected by the polygonal mirror. The deflected laser beam is converged by the  $f\theta$  lens and forms a beam spot on a surface to be scanned. Since the polygonal mirror is rotated, the deflected beam scans within a predetermined angular range. Thus, the beam spot formed on the surface to be scanned moves along a predetermined

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scanning line, extending direction of which will be referred to as a main scanning direction. The surface to be scanned is a circumferential surface of a photoconductive drum. By using the plurality of scanning optical systems and the corresponding photoconductive drums for a plurality of color components, respectively, a plurality of color image components are printed, in an overlaid fashion, on the same sheet so that a color image is formed.

In such a tandem type color printer, i.e., a printer employing a plurality of scanning optical systems and photoconductive drums, in order to avoid color drift of an image, writing start position and writing end position of each scanning line of each color component should be adjusted accurately.

However, if the f $\theta$  lens of each scanning optical system has lateral chromatic aberration, and wavelength of a laser beam emitted by each laser diode has individual errors, then the writing start and/or end positions of the scan line may be different among the color components. In such a case, the color drift appear on a printed image and the quality of the formed image is deteriorated.

#### Summary of the Invention

It is therefore an object of the present invention to

provide an improved tandem type scanning optical system which is capable of preventing the color drift due to variation of wavelengths among the laser beams emitted by a plurality of light sources, and due to uneven distribution of refractive index caused by uneven temperature distribution inside the printer.

For the above object, according to the present invention, there is provided a tandem type printer that includes a plurality of scanning optical systems respectively having plurality of  $f\theta$  lenses, and photoconductive drums, which correspond to the scanning optical systems, respectively. Each scanning optical system includes a laser source and a deflector that deflects the laser beam emitted by the laser source to scan, in a main scanning direction, within a predetermined angular range. The deflected laser beam is converged by the  $f\theta$  lens on the corresponding photoconductive drum and form an image. Images formed on the plurality of photoconductive drums are developed and transferred on a sheet in an overlaid fashion. Each  $f\theta$  lens includes a glass lens that is burdened with substantially all the power, in the main scanning direction, of the  $f\theta$  lens, and a plastic lens that is burdened with compensation for aberrations of the  $f\theta$  lens. Further, a diffraction lens structure is formed to compensate for a lateral chromatic aberration of the  $f\theta$  lens in the main

scanning direction. Each  $f\theta$  lens satisfies conditions:

$$0.0 < f_a/f_d < 0.20; \text{ and}$$

$$0.75 < f_a/f_g < 1.20,$$

where,  $f_a$ ,  $f_d$  and  $f_g$  represent focal lengths of the  
5  $f\theta$  lens, diffraction lens structure, and glass lens, in the  
main scanning direction, respectively.

With this configuration, the lateral chromatic  
aberration is compensated by the diffraction lens structure.  
Further, since the glass lens is mainly burdened with the  
10 power in the main scanning direction, and change of  
refractive index due to variation of temperature affects  
little. Therefore, with a printer employing the scanning  
optical system according to the present invention, color  
drift of printed images due to variation of wavelengths of  
15 the laser beams for respective color components, and due to  
uneven distribution of temperature inside the printer can  
be suppressed, and color images can be printed accurately.

Optionally, the diffraction lens structure may be  
formed on a refraction surface of said plastic lens in each  
20  $f\theta$  lens.

#### Brief Description of the Accompanying Drawings

Fig. 1 is a side view of a tandem type printer  
25 illustrating an arrangement of optical elements therein;

Fig. 2 is a plan view of the scanning optical system according to a first embodiment;

Fig. 3 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 2;

5 Fig. 4 is a plan view of the scanning optical system according to a second embodiment;

Fig. 5 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 4;

10 Fig. 6 is a plan view of the scanning optical system according to a third embodiment; and

Fig. 7 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 6.

15 Detailed Description of the embodiments

Hereinafter, the embodiments according to the invention will be described in detail with reference to the accompanying drawings.

20 Fig. 1 is a side view of a printer to which embodiments according to the present invention can be applied. The printer shown in Fig. 1 is configured such that a color image is formed by printing black, cyan, yellow and magenta images on a sheet in an overlaid fashion.

25 For this purpose, the printer includes a plurality of

scanning optical systems and photoconductive drums for the black, cyan, yellow and magenta components, respectively.

The printer shown in Fig. 1 has a housing 10 and a drum support 20. The housing 10 accommodates first through fourth scanning optical systems 100, 200, 300 and 400. The drum support 20 rotationally supports first through fourth photoconductive drums 21, 22, 23 and 24, which are exposed to scanning beams emitted from the first through fourth scanning optical system 100-400, respectively. The first through fourth photoconductive drums 21-24 are arranged such that rotation axes thereof are parallel to each other. Units (e.g., a developing unit, a transfer unit, a cleaning unit) for performing an electronic image forming process are provided around each of the photoconductive drums 21-24. Since such units are well-known, they are not shown in the drawing and description thereof is omitted for the sake of simplicity.

In the printer, a recording sheet is fed from a left-hand side to a right-hand side of Fig. 1 along a sheet feed path R. Then, toner images of respective color components (i.e., black, cyan, yellow and magenta components) are transferred from the first to fourth photoconductive drums 21-24 sequentially, thereby a color image being finally formed on the recording sheet. The color image thus transferred on the recording sheet is fixed thereon by a

fixing unit. The fixing process is also well-known in the field of electrophotographic process, and therefore, it is not shown in Fig. 1 and a detailed description will not be given.

5       Next, a configuration of the first scanning optical system 100 will be described in detail with reference to Figs. 1 and Fig. 2, which is a plan view showing an arrangement of optical elements of the first scanning optical system 100. It should be noted that all the  
10 scanning optical systems 100-400 are structurally the same, and therefore what is described in connection with the first scanning optical system 100 also applies to the other scanning optical systems 200-400.

As shown in Figs. 1 and 2, the first scanning optical  
15 system 100 is provided with:

a laser source unit 110 for emitting a collimated laser beam;

a polygonal mirror 120 for deflecting the collimated laser beam to scan, in a main scanning direction, within a  
20 predetermined angular range; and

an  $f\theta$  lens 130 for converging the scanning laser beam on the circumferential surface of the photoconductive drum 21 to form a scanning line thereon. Strictly speaking, the laser beam passed through the  $f\theta$  lens 130 is reflected by a  
25 mirror 140 (see Fig. 1), and then converged on the surface

of the photoconductive drum 21. However, since the mirror 140 functions only to bend an optical path, Fig. 2 is drawn as a developed view, omitting the mirror 140 therefrom. In Fig. 1, a rectangular coordinate system indicated by upper cases XYZ is shown. In Fig. 2, another rectangular coordinate system indicated by lower cases xyz is shown. In Fig. 1, the main scanning direction is defined as Y-axis direction, and an auxiliary scanning direction, which is perpendicular to the main scanning direction on the surface of the photoconductive drum 21, is defined as X-axis direction. In Fig. 2, the main scanning direction is defined as the y-axis direction, and the auxiliary scanning direction is defined as the z-axis direction.

As shown in Fig. 2, the laser source unit 110 includes a laser diode 111, and a collimating lens 112 for collimating the laser beam emitted by the laser diode 111. A cylindrical lens 115, which has positive power in the auxiliary scanning direction, is provided between the laser source unit 110 and the polygonal mirror 120. It should be noted that, in Fig. 1, the auxiliary direction at the photoconductive drum 21 is the X-axis direction. However, the auxiliary direction at the cylindrical lens 115 is the Z-axis direction since the laser beam is reflected by the mirror 140. In Fig. 2, since the mirror 140 is omitted from the drawing, the auxiliary direction is referred to as the



z-axis direction both at the photoconductive drum 21 and at the cylindrical lens 115.

The  $f\theta$  lens 130 includes a first lens 131 and a second lens 132. Further, on a photoconductive drum side surface of the first lens, a Fresnel lens like diffraction lens structure 131a is formed. The first lens 131 is a plastic lens and burdened with (functions to) compensation for aberrations (e.g., curvature of field in the main scanning direction and errors of  $f\theta$  characteristics). The second lens 132 is a glass lens and provides almost all the power, in the main scanning direction, of the  $f\theta$  lens 130. The diffraction lens structure 131a is formed as a part of a pattern rotationally symmetrical about an optical axis of the  $f\theta$  lens 130 and has a plurality of annular zones. The diffraction lens structure 131a functions to compensate for lateral chromatic aberration, in the main scanning direction, of the refractive lens structure of the  $f\theta$  lens 130.

The laser beam deflected by the polygonal mirror 120, and passed through the first and second lenses 131 and 132 of the  $f\theta$  lens 130 is, as shown in Fig. 1, reflected by a mirror 140 downward and incident on the first photoconductive drum 21. The polygonal mirror 120 rotates clockwise, in Fig. 2, and the deflected beam scans on the circumferential surface of the photoconductive drum in the

main scanning direction, i.e., in the y-axis direction in Fig. 2.

The collimated laser beam emitted by the laser source 110 is converged, only in the auxiliary scanning direction, on a plane closely adjacent to the reflection surface of the polygonal mirror 120. Then, the beam is deflected by the polygonal mirror 120, and is converged, by the  $f\theta$  lens 130, on the photoconductive drum 21. With this configuration, facet error of the reflection surfaces of the polygonal mirror 120 can be compensated, and therefore, shift of the scanning line, in the auxiliary scanning direction, on the photoconductive drum 21 due to the facet error can be prevented.

As aforementioned, the second through fourth scanning optical systems 200-400 are configured similarly to the first scanning optical system 100. That is, the second scanning system 200 includes a laser source (not shown), a polygonal mirror 220 and an  $f\theta$  lens 230 including first and second lenses, and a mirror 240. The second scanning system 200 forms a scanning line on the circumferential surface of the second photoconductive drum 22. The third scanning system 300 includes a laser source (not shown), a polygonal mirror 320 and an  $f\theta$  lens 330 including first and second lenses, and a mirror 340. The third scanning system 300 forms a scanning line on the circumferential surface of the

third photoconductive drum 23. The fourth scanning system 400 includes a laser source (not shown), a polygonal mirror 420 and an  $f\theta$  lens 430 including first and second lenses, and a mirror 440. The fourth scanning system 400 forms a scanning line on the circumferential surface of the third photoconductive drum 24.

Next, the structure of the  $f\theta$  lens 130 will be described, and then numerical examples of the  $f\theta$  lens 130 will be explained as three embodiments.

As aforementioned, the  $f\theta$  lens 130 includes the first and second refractive lenses 131 and 132, and the diffraction lens structure 131a.

It is well-known that the diffraction lens structure has a dispersion, an absolute value of which is relatively large and sign of which is negative. Therefore, by combining the diffractive lens structure, having relatively small power, with the refractive lens, the lateral chromatic aberration can be compensated.

In order to reduce the lateral chromatic aberration and variation of the power due to a change of refractive index caused by a change in temperature, according to the embodiment, a glass lens is included in the  $f\theta$  lens 130. The glass lens provides almost all the power in the main scanning direction.

Specifically, as aforementioned, the  $f\theta$  lens 130 is

constructed to have the plastic lens (first lens) 131 which has almost no power in the main scanning direction and the glass lens (the second lens) 132 which provides almost all the power, in the main scanning direction, of the f $\theta$  lens 130. Since the glass lens 132 provides almost all the power of the f $\theta$  lens 130 in the main scanning direction, a change of power, due to a change of temperature, of the glass lens is very small, variation of power of the f $\theta$  lens 130 is well prevented. Further, by the diffraction lens structure 131a, in association with the refractive lenses 131 and 132, the lateral chromatic aberration can be compensated.

More specifically, the second lens 132 and the diffractive lens structure 131a are designed to satisfy conditions (1) and (2) below:

$$0.0 < f_a/f_d < 0.20 \quad \dots (1)$$

$$0.75 < f_a/f_g < 1.20 \quad \dots (2)$$

where,  $f_a$  represents a focal length, in the main scanning direction, of the f $\theta$  lens 130;

$f_d$  represents a focal length, in the main scanning direction, of the diffraction lens structure 131a; and

$f_g$  represents a focal length, in the main scanning direction, of the second (glass) lens 132.

Conditions (1) and (2) define, in other words, the upper and lower limits of the power of the glass lens 132

and the diffraction lens structure 131a normalized by the power of the  $f\theta$  lens 130.

In condition (1), if  $f_a/f_d$  is negative (i.e., smaller than 0.0), the lateral chromatic aberration of the diffractive lens structure 131a and that of the refractive lens structure are directed in the same direction, and therefore, the lateral chromatic aberration cannot be compensated by combining the diffractive lens structure 131a with the refractive lens structure. If  $f_a/f_d$  is greater than 0.20, the power of the diffraction lens structure 131a is too large, and the lateral chromatic aberration is overcorrected.

In condition (2), if  $f_a/f_g$  is smaller than 0.75, the power of the glass lens 132 is too small, and a positive power burdened by the plastic lens 131 is too large. If  $f_a/f_g$  exceeds 1.20, the power of the glass lens 132 is too large, and the amount of negative power provided by the plastic lens 131 is too large. In either case, the absolute value of the power provided by the plastic lens 131 is too large, which results in a relatively large change due to a change in temperature. Thus, if condition (2) is not satisfied, it is impossible to reduce both the lateral chromatic aberration and the change in power of the  $f\theta$  lens 130 due to the change of the temperature.

It should be noted that, in general, a diffraction

lens structure can be expressed by a sag amount  $SAG(h)$  representing a distance between a plane, which is tangent to the diffraction lens structure at a point where the optical axis intersects with the diffraction lens structure, and a point on the diffraction lens structure at height (a distance from the optical axis)  $h$ . The sag amount  $SAG(h)$  is obtained by the following formula (3).

$$SAG(h) = X(h) + S(h) \quad \dots (3)$$

where,  $X(h)$  represents a base curve of the surface on which the diffraction lens structure is formed. The base curve  $X(h)$  is expressed by the following formula (4).

$$X(h) = \left\{ \frac{ch^2}{1 + \sqrt{1 - (\kappa + 1) \cdot c^2 h^2}} \right\} + A4h^4 + A6h^6 + A8h^8 + A10h^{10} \quad \dots (4)$$

where,  $c = 1/r$ ,  $r$  represents radius of curvature on the optical axis,  $\kappa$  represents a conical coefficient,  $A4$ ,  $A6$ ,  $A8$  and  $A10$  represent fourth, sixth, eighth, and tenth aspherical coefficients.

An additional optical path length  $\Delta\phi(h)$  to be added by the diffraction lens structure is obtained by the following formula (5).

$$\Delta\phi(h) = P2h^2 + P4h^4 + P6h^6 + P8h^8 + P10h^{10} \quad \dots (5)$$

where,  $P_n$  represents an  $n$ -th ( $n$  being an even number) order coefficient of an optical path difference function. The term  $S(h)$  in formula (3) is calculated in accordance with the following formula (6).

$$S(h) = \frac{\{MOD(\Delta\phi(h) + C, -1) - C\} \cdot \lambda}{n - 1 + Dh^2} \quad \dots (6)$$

where, C is a constant for setting a phase of boundaries of the annular zones, and can be any desired value between 0 and 1 (C=0.5 in the following examples),

5 and

D represents a coefficient to compensate for variation of additional phase which is caused as the light beam impinges on the diffraction lens structure obliquely,

$\lambda$  represents a wavelength of the light beam.

10 As is known, MOD is a modulo function and MOD(a,b) is defined as:

$$MOD(a,b) = a - b \cdot INT(a/b).$$

A zone number corresponding to each zone is expressed by the formula (7).

$$15 \quad N = INT(\Delta\phi(h) + C) \quad \dots (7)$$

where, N=0 corresponds to a zone intersecting with the optical axis.

#### FIRST EMBODIMENT

20 Fig. 2 is a plan view of the scanning optical system 1000, showing an arrangement of optical elements, according to a first embodiment of the invention. In TABLE I, numerical structure of the optical elements, on the photoconductive drum side thereof with respect to the

cylindrical lens is indicated. In TABLE I,  $f_a$  denotes a focal length of the  $f\theta$  lens 130 in the main scanning direction,  $r_y$  denotes a radius of curvature in the main scanning direction (i.e., y-axis direction in Fig. 2),  $r_z$  denotes a radius of curvature (which is omitted for a rotationally symmetrical surface) in the auxiliary scanning direction (i.e., z-axis direction in Fig. 2),  $d$  denotes a distance between adjacent surfaces on the optical axis, and  $n$  denotes a refractive index at wavelength of 780 nm.

In TABLE I, surface #1 and #2 are the surfaces of the cylindrical lens 115, surface #3 is a mirror surface of the polygonal mirror 120, surfaces #4 and #5 are the surfaces of the first lens 131, and surfaces #6 and #7 are those of the second lens 132.

TABLE I

$f_a=199.9$  mm    scan width:320 mm    design  $\lambda$ : 780 nm

No.	$r_y$	$r_z$	$d$	$n$
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
#3	inf.	--	67.00	
#4	-378.99	-30.95	8.00	1.48617
#5	-491.66	--	5.00	



#6                inf.                18.00                1.76591  
 #7                -154.30                -30.13                201.25

Surface #4 is an aspherical surface, which does not  
 5 have an axis of symmetry. A radius of curvature of a cross  
 section of surface #4 taken along a plane parallel to an x-  
 z plane spaced from the optical axis is set independently  
 from the cross section taken along an x-y plane.  
 Hereinafter, such a surface will be referred to as a  
 10 progressive toric aspherical surface, which is expressed by  
 the following formula (8).

$$x(y) = \frac{cy^2}{1 + \sqrt{1 - (\kappa + 1)c^2y^2}} + A4y^4 + A6y^6 + A8y^8 + A10y^{10} \dots (8)$$

where,  $c = 1/r$ , and  $\frac{1}{Rz} = \frac{1}{Rzo} + B1y + B2y^2 + B3y^3 + B4y^4$ .

15 In the above equations, y represent an image height  
 in the y-axis (i.e., the main scanning) direction, r  
 denotes a radius of curvature, in the main scanning  
 direction, on the optical axis. Curvature in the z-axis  
 direction, at the height y in the main scanning direction,  
 20 is represented by  $1/Rz$ , and  $Rzo$  represents a radius of  
 curvature, in the auxiliary scanning direction, on the  
 optical axis (i.e.,  $y=0$ ). B1, B2, B3 and B4 represent  
 coefficients representing change of the radius of curvature

in the auxiliary scanning direction.

Surface #5 is a surface on which the diffraction lens structure is formed, surface #6 is a planar (flat) surface, and surface #7 is a toric surface having an axis, which extends in the auxiliary scanning direction, of symmetry.

That is, surface #7 is rotationally symmetrical about the axis. Such a toric surface will be referred to as a Z toric surface hereinafter. Conical coefficients and aspherical coefficients are indicated in TABLE II, while, a numerical structure of surface #5 (i.e., the diffraction lens structure) is indicated in TABLE III.

TABLE II

Aspherical coefficients for surface #4

K	0.0		
A4	$-1.782 \times 10^{-6}$	B1	$-4.081 \times 10^{-5}$
A6	$8.076 \times 10^{-10}$	B2	$-1.757 \times 10^{-5}$
A8	$-1.134 \times 10^{-13}$	B3	0.0
A10	0.0	B4	$3.005 \times 10^{-9}$

TABLE III

fd at design wavelength: 3443.6 mm

### Macroscopic shape

	r	-491.66
5	k	0.0
	A4	$-1.282 \times 10^{-6}$
	A6	$5.012 \times 10^{-10}$
	A8	$-5.585 \times 10^{-14}$
	A10	0.0

### Coefficients for additional path length $\Delta\phi(h)$

	P2	$-1.8615 \times 10^{-1}$
	P4	$-1.0817 \times 10^{-5}$
	P6	$1.5024 \times 10^{-9}$
15	P8	$-3.1306 \times 10^{-12}$
	P10	$4.0862 \times 10^{-16}$
	D	$1.34 \times 10^{-5}$

Fig. 3 is a graph showing the lateral chromatic aberration of the scanning optical system according to the first embodiment.

### SECOND EMBODIMENT

Fig. 4 is a plan view of the scanning optical system 2000, showing an arrangement of optical elements, according

to a second embodiment of the invention. The scanning optical system 2000 include an f $\theta$  lens 130a, which includes a first lens 133, a second lens 134, and a diffraction lens structure 133a formed on a surface of the first lens 133.

5 The first lens 133 is a plastic lens, and the second lens 134 is a glass lens. In TABLE IV, a numerical structure of the optical elements, on the photoconductive drum side thereof with respect to the cylindrical lens is indicated.

In TABLE IV, fa denotes a focal length of the f $\theta$  lens 130a

10 in the main scanning direction, ry denotes a radius of curvature in the main scanning direction, rz denotes a radius of curvature in the auxiliary scanning direction (which is omitted for a rotationally symmetrical surface), d denotes a distance between adjacent surfaces on the optical axis, and n denotes a refractive index at a  
15 wavelength of 780 nm.

TABLE IV

20 fa=200.0 mm scan width: 320 mm design  $\lambda$ : 780 nm

No.	ry	rz	d	n
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
25 #3	inf.	--	67.00	

#4	568.65	-23.70	7.40	1.48617
#5	7235.14	--	4.00	
#6	inf.	--	21.50	1.51072
#7	-123.77	-19.40	195.65	

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Surface #4 is a progressive toric aspherical surface, surface #5 is a surface on which the diffraction lens structure is formed, surface #6 is a planar surface, and surface #7 is a Z toric surface. Conical coefficients and aspherical coefficients for surface #4 are indicated in

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TABLE V, and the numerical structure of the diffraction lens structure on surface #5 is indicated in TABLE VI.

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TABLE V

fd at the design wavelength: 5677.4 mm

## Macroscopic shape

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r	7235.14
$\kappa$	0.0
A4	$-1.670 \times 10^{-6}$
A6	$2.655 \times 10^{-10}$
A8	$-1.900 \times 10^{-14}$
A10	0.0

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Coefficients for additional path length  $\Delta\phi(h)$

	P2	$-1.1291 \times 10^{-1}$
	P4	$6.0796 \times 10^{-7}$
	P6	$-3.0940 \times 10^{-9}$
5	P8	$2.3439 \times 10^{-13}$
	P10	$-7.7883 \times 10^{-17}$
	D	$8.17 \times 10^{-6}$

Fig. 5 is a graph showing the lateral chromatic  
10 aberration of the scanning optical system according to the  
second embodiment.

### THIRD EMBODIMENT

Fig. 6 is a plan view of the scanning optical system  
15 3000, showing an arrangement of optical elements, according  
to a third embodiment of the invention. The scanning  
optical system 3000 include an  $f\theta$  lens 130b, which includes  
a first lens 135, a second lens 136, and a diffraction lens  
structure 135a formed on a surface of the first lens 135.

20 The first lens 135 is a plastic lens, and the second lens  
136 is a glass lens. In TABLE VII, a numerical structure of  
the optical elements, on the photoconductive drum side  
thereof with respect to the cylindrical lens is indicated.

In TABLE VII,  $f_a$  denotes a focal length of the  $f\theta$  lens 130b  
25 in the main scanning direction,  $r_y$  denotes a radius of

curvature in the main scanning direction,  $r_z$  denotes a radius of curvature in the auxiliary scanning direction (which is omitted for a rotationally symmetrical surface),  $d$  denotes a distance between adjacent surfaces on the optical axis, and  $n$  denotes a refractive index at wavelength of 780 nm.

TABLE VII

fa=199.7 mm    scan width: 320 mm    design  $\lambda$ : 780 nm

No.	$r_y$	$r_z$	$d$	$n$
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
#3	inf.	--	68.00	
#4	-207.48	--	8.70	1.48617
#5	-264.05	-56.42	3.00	
#6	inf.	--	20.00	1.76591
#7	-149.04	-51.23	202.73	

Surface #4 is a surface on which the diffraction lens structure is formed, surface #5 is a progressive toric aspherical surface, surface #6 is a planar surface, and surface #7 is a Z toric surface. The numerical structure of

the diffraction lens structure on surface #4 is indicated in TABLE VIII, and the conical coefficients and aspherical coefficients for surface #5 are indicated in TABLE IX.

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TABLE VIII

fd at design wavelength: 3700.3 mm

## 10 Macroscopic shape

r	-207.48
k	0.0
A4	$-1.472 \times 10^{-6}$
A6	$6.166 \times 10^{-10}$
A8	$-7.251 \times 10^{-14}$
A10	0.0

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Coefficients for additional path length  $\Delta\phi(h)$ 

P2	$-1.7324 \times 10^{-1}$
P4	$-1.1333 \times 10^{-4}$
P6	$3.8473 \times 10^{-8}$
P8	$-9.3384 \times 10^{-12}$
P10	$1.1066 \times 10^{-15}$
D	$2.59 \times 10^{-5}$

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TABLE IX

Conical and aspherical coefficients for surface #5

	K	0.0		
5	A4	$-8.901 \times 10^{-7}$	B1	$2.157 \times 10^{-5}$
	A6	$3.352 \times 10^{-10}$	B2	$2.310 \times 10^{-6}$
	A8	$-3.235 \times 10^{-14}$	B3	0.0
	A10	0.0	B4	$5.929 \times 10^{-10}$

Fig. 7 is a graph showing the lateral chromatic aberration of the scanning optical system according to the third embodiment.

TABLE X indicates values  $f_a/f_d$  and  $f_a/f_g$  of each embodiment.

TABLE X

	condition	1st emb.	2nd emb.	3rd emb.
20	$0.0 < f_a/f_d < 0.20$	0.06	0.04	0.05
	$0.75 < f_a/f_g < 1.20$	0.99	0.83	1.03

As is known from TABLE X, in each embodiment, conditions (1) and (2) are satisfied. Therefore, in each embodiment, the lateral chromatic aberration and variation

of power due to a change of refractive index can be suppressed. Therefore, with a printer employing the scanning optical system according to the present invention, color drift of printed images due to variations of wavelengths of the laser beams for respective color components, and due to uneven distribution of temperature inside the printer can be suppressed, and color images can be printed accurately.

The present disclosure relates to the subject matter  
10 contained in Japanese Patent Application No. HEI 11-248465,  
filed on September 2, 1999, which is expressly incorporated  
herein by reference in its entirety.

18722	18723	18724	18725	18726	18727	18728	18729	18730	18731	18732	18733	18734	18735	18736	18737	18738	18739	18740	18741	18742	18743	18744	18745	18746	18747	18748	18749	18750	18751	18752	18753	18754	18755	18756	18757	18758	18759	18760	18761	18762	18763	18764	18765	18766	18767	18768	18769	18770	18771	18772	18773	18774	18775	18776	18777	18778	18779	18780	18781	18782	18783	18784	18785	18786	18787	18788	18789	18790	18791	18792	18793	18794	18795	18796	18797	18798	18799	18800	18801	18802	18803	18804	18805	18806	18807	18808	18809	18810	18811	18812	18813	18814	18815	18816	18817	18818	18819	18820	18821	18822	18823	18824	18825	18826	18827	18828	18829	18830	18831	18832	18833	18834	18835	18836	18837	18838	18839	18840	18841	18842	18843	18844	18845	18846	18847	18848	18849	18850	18851	18852	18853	18854	18855	18856	18857	18858	18859	18860	18861	18862	18863	18864	18865	18866	18867	18868	18869	18870	18871	18872	18873	18874	18875	18876	18877	18878	18879	18880	18881	18882	18883	18884	18885	18886	18887	18888	18889	18890	18891	18892	18893	18894	18895	18896	18897	18898	18899	18900	18901	18902	18903	18904	18905	18906	18907	18908	18909	18910	18911	18912	18913	18914	18915	18916	18917	18918	18919	18920	18921	18922	18923	18924	18925	18926	18927	18928	18929	18930	18931	18932	18933	18934	18935	18936	18937	18938	18939	18940	18941	18942	18943	18944	18945	18946	18947	18948	18949	18950	18951	18952	18953	18954	18955	18956	18957	18958	18959	18960	18961	18962	18963	18964	18965	18966	18967	18968	18969	18970	18971	18972	18973	18974	18975	18976	18977	18978	18979	18980	18981	18982	18983	18984	18985	18986	18987	18988	18989	18990	18991	18992	18993	18994	18995	18996	18997	18998	18999	19000
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